PATENT SPECIFICATION

Application Date: Sept. 25, 1936. No. 26068/36.

468,548

Complete Specification Accepted: July 7, 1937.

COMPLETE SPECIFICATION

Improvements in or relating to High Frequency Signalling Systems or Apparatus

Communicated by WESTERN ELECTRIC COMPANY INCORPORATED, a Corporation of the State of New York, having a principal place of business at 195, Broadway, New York, United States of America.

We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of Connaught House, 63, Aldwych, London, W.C.2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to the propagation of electromagnetic waves in dielectric guides.

According to one feature of the invention we provide new and improved apparatus and a corresponding method by which electromagnetic waves of a certain type under propagation in a dielectric guide may be modified or reshaped so that they will go on as waves of a different type. Another feature of the invention is to provide for the introduction of conductive baffles or deflectors in a dielectric guide, such baffles being so shaped and proportioned that they will bend the lines of force of incoming electromagnetic waves in the guide and reshape them to give outgoing waves of another type. These and other features and advantages of our invention will become apparent on consideration of a limited number of examples of the invention which we have chosen for presentation in the following specification. It will be understood that this disclosure relates principally to these particular embodiments of the invention and that the scope of the invention will be indicated in the appended claims.

Referring to the accompanying drawings, Figures 1, 3, 5 and 7 are longitudinal sections of a dielectric guide showing wave shapes of different types;

Figs. 2, 4, 6 and 8 are respective cross sections;

Fig. 9 is a longitudinal section, partly in elevation, showing a converter for changing asymmetric magnetic waves to symmetric magnetic waves;

Fig. 10 is a set of cross sections of Fig. 9;

Fig. 11 is a pair of diagrammatic cross sections showing a modification of the device of Figs. 9 and 10;

Fig. 12 is a longitudinal section, partly in elevation, showing a converter for changing second order asymmetric magnetic waves to first order symmetric magnetic waves;

Fig. 13 is a set of cross sections of Fig. 12;

Fig. 14 is a diagram indicating one way in which second order asymmetric magnetic waves may be generated;

Fig. 15 is a longitudinal section of a converter for changing electromagnetic waves from asymmetric magnetic type to asymmetric electric type;

Fig. 16 is a set of cross sections of Fig. 15;

Fig. 17 is a longitudinal section showing a converter for changing asymmetric electric waves to asymmetric magnetic waves;

Fig. 18 is a set of cross sections of Fig. 17;

Fig. 19 is a longitudinal section, partly in elevation, showing a converter for changing asymmetric electric waves to symmetric magnetic waves;

Figs. 20 and 21 are cross sections taken on the correspondingly numbered lines of Fig. 19;

Fig. 22 is a perspective side view, partly in section, of a converter adapted to change symmetric electric waves to asymmetric electric waves;

Fig. 23 is a set of cross sections corresponding to Fig. 22;

Fig. 24 is a longitudinal section showing a converter for changing asymmetric magnetic waves to symmetric magnetic waves;

Fig. 25 is a set of cross sections of Fig. 24;

Fig. 26 is a perspective side view,

[Pric

partly in section, showing a converter for changing symmetric electric waves to asymmetric magnetic waves;

Fig. 27 is a set of cross sections of Fig. 26;

Fig. 28 is a perspective side view, partly in section, showing a converter for changing symmetric electric waves to asymmetric magnetic waves;

Fig. 29 is a set of cross sections of Fig. 28;

Fig. 30 is a perspective side view, partly in section showing a converter for changing symmetric electric waves to asymmetric magnetic waves;

Fig. 31 is a set of cross sections of Fig. 30;

Fig. 32 is a side elevation, partly in section, showing a converter adapted to change symmetric electric waves to symmetric magnetic waves;

Figs. 33 and 34 are cross sections indicated by corresponding lines on Fig. 32;

Fig. 35 is a perspective view, partly in section, showing a converter for changing symmetric electric waves to symmetric magnetic waves; and

Fig. 36 is a set of cross sections of Fig. 35.

The term dielectric guide used in this specification is meant to indicate a body of dielectric extending from one place to another place and bounded laterally by a dielectric discontinuity. Such a dielectric guide functions by the generation therein at the one place of electromagnetic waves and their propagation therein to the other place. A form of dielectric guide which will be convenient for consideration in this connection consists of a cylindrical body of air or empty space as the dielectric, extending from the one place to the other, and having an enclosing cylindrical sheath which affords the dielectric discontinuity for a lateral boundary.

There are different types of waves which may be propagated in such a dielectric guide. If the waves have substantial components of electric force parallel to the axis of the guide they are called electric, but if they have substantial components of magnetic force in that direction they are called magnetic. If the lines of force are symmetric on all sides of the axis of the guide they are called symmetric, but if the lines of force have a substantial component parallel to a plane containing the axis they are called asymmetric.

Referring to Figs. 1 to 8 of the present application, these are diagrammatic longitudinal and cross sections of an air-core metal-sheathed dielectric guide with the thickness of the sheath greatly exaggerated to facilitate the disclosure. In those figures continuous lines represent lines of electric force, and dotted lines represent lines of magnetic force. It will readily be appreciated, from what has been said, that symmetric electric waves are represented in Figs. 1 and 2; symmetric magnetic waves in Figs. 3 and 4; asymmetric electric waves in Figs. 5 and 6, and asymmetric magnetic waves in Figs. 7 and 8. All these are first order waves. Certain waves of second order will be mentioned in connection with Figs. 12, 13 and 14.

The present invention has to do in great measure with the provision of a method and apparatus for converting one type of wave into another type of wave. Such a conversion may be useful when one has a generator associated with the dielectric guide at the transmitting end so that waves of one type are produced and it is desired to transmit waves of a different type; or when waves of one type are received through a dielectric guide and it is more convenient to receive another type, into which, accordingly, the first type may be converted. In any such case a wave converter of the present invention may be employed.

Asymmetric magnetic waves coming from the left of the dielectric guide D of Fig. 9, with their lines of force directed up and down as viewed in this figure, are caught and bisected by the intermediate edge 110 of the two pipes 111 and 112, each with kidney-shaped cross section at their place of junction with the main guide D. Going on to the right, each of these two pipes is gradually brought to a circular section as in the third of the cross sections of Fig. 10. Then continuing on to the right, each circular pipe has a baffle which begins with a horizontal edge at 113 and 114 and twists in helical form 90 degrees, the upper one to the right and the lower one to the left. Thus the lines of force which are directed alike along a vertical diameter of the main guide D at 113 and 114 are directed oppositely across the same diameter at 115 and 116. These lines are then launched from the open ends of the two circular pipes at 115 and 116 into the enlarged circular pipe D^1, and they link together, giving the transverse circular lines of force which are characteristic of the symmetric magnetic waves.

Whereas two branch pipes were shown linking the guide D on the left with the guide D^1 on the right in Figs. 9 and 10, four such pipes may be employed as indicated in the diagrams of Fig. 11. The electric lines of force of the asymmetric magnetic waves will be received in these

four pipes with the directions indicated by the arrows in the upper diagram of Fig. 11. The baffles with helical twist will turn the lines of force 90 degrees clockwise in the upper pipe; 90 degrees counter-clockwise in the lower pipe; 180 degrees in the right-hand pipe, and no rotation in the left-hand pipe. These component lines of force, thus directed, as in the lower diagram of Fig. 11, will be launched forth and will link up to give the transverse circular lines of force characteristic of the symmetric magnetic type of waves.

For the output of the system of Figs. 9 and 10, or of Fig. 11, it may be desirable to provide a screen of circular wires, like those shown at 105 in Fig. 25, which will purify the outgoing wave to the symmetric magnetic type. Since the lines of electric force of the outgoing symmetric magnetic waves will cut the radial wires of the screen 105 each at a right angle, there will be no tendency to develop electromotive forces in those radial conductors; there will be no loss of energy from the wave to the conductors, and the symmetric magnetic wave will pass through and go on unimpaired. But if its lines of force have components other than the circles centred on the axis and in planes perpendicular thereto, those other components will tend to set up currents in the radial conductors 105 and their energy will be absorbed or reflected thereby. In this way the screen 105 may be called a purifier for the symmetric magnetic waves passing through it.

Before explaining the conversion effected by the apparatus of Figs. 12 and 13, attention is directed to the fact that heretofore the waves considered have been of first order type. But it is possible to generate waves in dielectric guides with more elaborate or complex grouping of the lines of force in what may properly be called wave types of higher order. The waves of asymmetric magnetic type of the first order may be generated by an oscillator connected to two diametrically opposite points within a dielectric guide at the left, as shown in Fig. 9. But if the oscillator is connected to points a quadrant distance around the circumference, as shown in Fig. 14, the oscillatory currents will develop lines of force as shown in that figure, corresponding to what may properly be called asymmetric magnetic waves of the second order.

Let such waves be generated in the dielectric guide of Fig. 12 coming from the left, and let four helical baffles 120 be introduced in the guide having the shapes indicated by the successive cross sections of Fig. 13. That is, the upper and lower baffles have a 90-degree counter-clockwise twist and the right and left baffles have a 90-degree clockwise twist. In this way the lines of force of the waves of second order asymmetric magnetic type incoming on the left are broken up and bent around and reconnected so as to give the outgoing waves of symmetric magnetic type on the right.

Asymmetric magnetic waves coming from the left in Fig. 15 have their lines of electric force caught between the opposed conductors 101 and 102 and gradually reshaped until they are launched to the right as asymmetric electric waves. The conductors 101 and 102 close at the right to form two pipes each of kidney shape in cross section. Within each such pipe is an adjustable piston 103 by which an optimum conversion with impedance match may be obtained.

Another converter to operate either way between asymmetric electric waves and asymmetric magnetic waves is shown in Figs. 17 and 18. Incoming asymmetric electric waves from the left fix the ends of their lines of force upon the left-hand ends of the opposite kidney-shaped electrodes 106 and 107. These electrodes going from left to right are spread apart and opened out into part cylindrical shells, and the lines of force are stretched out between them so that on the right they are launched forth as asymmetric magnetic waves.

Asymmetric electric waves coming from the left in Fig. 19 have their lines of force picked up by the two kidney-shaped electrodes 46 having the cross section shown in Fig. 20. The conductors from these kidney-shaped electrodes are gradually deformed, going from left to right, as indicated in Fig. 19, until they make a coaxial conductor system as shown at 44 and 43. Then the inner and outer conductors 44 and 43 are connected, respectively, at the middle points of the two intersecting parts of the figure-8 frame shown at 40 in Figs. 19 and 21. In this frame it will be seen that when the currents circulate clockwise in the upper member they also circulate clockwise in the lower member. Thus from this frame circular lines of electric force are detached and launched forward to the right as symmetric magnetic waves in the dielectric guide.

Referring to Figs. 22 and 23, it is assumed that waves of symmetric electric type, such as diagrammed in Figs. 1 and 2, are propagated along the dielectric guide D from the left and it is desired to convert these into asymmetric electric waves outgoing in the guide D^1 on the

right. Beginning at 55 and continuing at 55^1 the inner metallic guide shell in continuation of shell D is opened along one side and bevelled and bent inside and its cross section contracted smoothly and gradually as shown in the sections of Fig. 23, until it ends in the kidney-shaped cross section shown at 56 in Fig. 23. Opposite the point 55 an inside coaxial conductor begins with a circular cross section as at 57. This is bevelled gradually and bent to one side until it ends in the kidney-shaped cross section 58 opposite 56. The cylinder D begins to expand as a frustrum of a cone at 55 and is continued to the right as at D^1 from the place 56—58, with increased diameter. The electric lines of force of the incoming symmetric electric waves approaching from the left are in part radially disposed, with their outer ends, to some extent, tied to the shell D. On arriving at the end 57 of the inner conductor they break and their inner ends attach to the shell 57 and they go on as coaxial conductor waves. The ratio of the inner and outer radii, as indicated at the second cross section of Fig. 23, is chosen at such a value as to give a proper impedance match between the dielectric guide D on the left and this coaxial conductor system having the inner conductor 57. Going on to the right, the lines of force are gradually redirected, extending across between the two conductors 55^1 and 57^1, and eventually, with their principal component parallel to a horizontal plane, they are launched from the ends 56, 58 into the part of the guide D^1 as asymmetric electric waves. To get a good impedance match throughout, it is desirable to make the diameter at D^1 somewhat greater than at D.

The system of Figs. 22 and 23 has been described as for conversion from symmetric electric to asymmetric electric, going from left to right. It will readily be apparent that the system may be employed for converting from asymmetric electric to symmetric electric, going from right to left.

In general, a wave type converter will be reversible; that is, if it converts from one type to another type going from left to right, it will convert back from the other type to the one type going from right to left. For definiteness and clearness, many of the appended claims are expressed in terms of conversion one way, but the method or apparatus of each such claim may be employed either way.

Referring to Figs. 24 and 25, the lines of electric force of asymmetric magnetic waves coming from the left are received on the conductors 154 which lie in a plane transverse to the axis of the dielectric guide D. These lines of force acting on the intermediate parts 154 of these conductors generate series-assisting electromotive forces in the circumferential parts 152 and 153 between which the parts 154 are connected. Also, these currents in the parts 152 and 153 are directed alike around the guide axis. From these circumferential segments, such as 152 and 153, the lines of force are detached and radiated on along the guide core, linking together in the form of the desired symmetric magnetic waves. A sieve of radial wires 105 is provided on the right to purify the symmetric magnetic waves, in other words, to block any component at that place which may be present corresponding to the input asymmetric magnetic waves which might tend to break through on the output side. A sieve of horizontal wires 106 at the left purifies the incoming waves against other components than those belonging to the asymmetric magnetic type.

Symmetric electric waves coming from the left of the dielectric guide D of Fig. 26, are received on the coaxial inner conductor 59 as coaxial conductor waves with their lines of electric force extending radially between the two conductors 59, and D. Each of these two conductors is split, one on one side and the other on the other side, as in the third of the cross sections of Fig. 27. The gap 60 in the outer shell may be filled with dielectric material as at 61. Going on to the right, the two splits are made wider and wider until in cross section each is about a semicircle, whereupon the inner member is expanded to the same size as the outer member; the corresponding cross section is shown in the diagram of Fig. 27. Finally, the two half shells are fused together giving an outgoing shell on the right of simple cylindrical contour. It will readily be seen that the radial lines of force which extend outwardly from the inner member at 59 become pushed over more and more past the edges of the cylindrical shell until eventually they stretch across horizontally from one side to the other and are launched to the right as asymmetric magnetic waves.

A somewhat different system for converting waves from symmetric electric to asymmetric magnetic is shown in Figs. 28 and 29. In view of the explanation that has gone before, it is believed that the transition will be readily apparent by noticing the arrows in Fig. 29 which indicate the electric lines of force of the progressively converted waves.

Yet another converter between the same two types is shown in Figs. 30 and

31. Here the incoming symmetric electric waves from the left are converted into coaxial conductor system waves with radial lines of force as shown in the first of the cross sections of Fig. 31. The central conductor is split as one goes from left to right and given a spiral cross section, with the outer end of the spiral connected eventually to the shell of the dielectric guide. Then going on from left to right, the inner part of the spiral is gradually cut away and the transverse lines of electric force of the waves are brought more and more to an approximately horizontal direction, until finally the wave is launched at the right as an asymmetric magnetic wave.

For effecting conversion of waves from symmetric electric type to symmetric magnetic type, the system of Figs. 32, 33 and 34 may be employed. Here the incoming symmetric electric waves from the left are received on the coaxial conductor system having the central core 51 and the outer shell D which is the shell of the dielectric guide. Thus at 51 the lines of force extend radially between these two conductors. The conductor 51 ends at the right in two arms 52, 53 bent around as shown in the cross section of Fig. 33 their ends 54 being adjacent the wall of the guide. The radial lines of force coming from the left are deflected by the extensions 52 and 53 and radiated therefrom to the right in the form of symmetric magnetic waves. The sieve of radial wires 54^1 blocks any superposed remnant of the symmetric electric waves and permits the passage to the right of only the purified resultant symmetric magnetic waves.

Figs. 35 and 36 show apparatus for the conversion of symmetric electric waves to symmetric magnetic waves. Symmetric electric waves of the character indicated in Figs. 1 and 2 are to be thought of as coming along the dielectric guide D of Fig. 35 from the left toward the right. At 75 there are flat members arranged side by side to form a cylindrical contour. The radii of the shell D and of the composite cylinder 75 are appropriate to match the impedances of the dielectric guide D on the left to the combination D—75 considered as a coaxial conductor.

Going on from left to right, each strip or plate 75 is given a progressive helical twist and at the same time is made wider; also, going from left to right over this same stretch from D to D^1, the diameter of the enclosing metallic sheath is increased gradually. Eventually, at the right, that is, at 75^1, each strip 75 has been twisted 90 degrees so that in a cross section at 75^1 each section is radial. At their ends 75^1, where the members extend radially, they nearly touch the inside wall of the metallic sheath D^1, but are spaced slightly therefrom.

The lines of force of the symmetric electric waves approaching from the left have substantial radial components and these are caught between the members 75 and D and extend radially as indicated in the left-hand section of Fig. 36. Progressing from left to right these lines of force gradually lose their connection to the surrounding shell D—D^1 and attach themselves each to the next adjacent segment in a circumferential direction until all the lines of force extend consecutively from one or another member 75^1 to the next member 75^1 in one direction around the guide. These various elemental lines of force then link together end to end as they are detached from the right-hand ends of the members 75^1 and progress to the right in the enlarged guide D^1 as the characteristic lines of electric force of symmetric magnetic waves.

The guide is enlarged from D to D^1 to preserve an impedance match throughout, the diameter at D being appropriate for symmetric electric waves of a certain frequency and that at D^1 being appropriate for symmetric magnetic waves of the same frequency.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. The method of generating waves of a certain type for propagation in a dielectric guide which consists in generating and transmitting waves of another type, receiving them as lines of force on a conductor system, guiding these lines on such conductor system so as to reshape them to the desired type, and detaching them from said conductor system to be propagated within the guide.

2. A dielectric guide provided with a conductor system therein for converting electromagnetic waves in said guide from one type to another type.

3. A dielectric guide provided with conductive baffles therein adapted to engage the ends of lines of force of incoming waves of one type in said guide and to deflect and reconnect such lines of force and detach them from the baffles in the shape of lines of force of another type of waves.

4. A dielectric guide as claimed in Claim 3 in which said baffles are bent in the direction of wave transmission so as to reshape the lines of force on them and discharge them in the direction of the outgoing waves to form such waves of a

different desired type.

5. A dielectric guide as claimed in Claim 3 comprising a plurality of helical baffles arranged side by side to act on different parts of the incoming wave front and rotate the lines of force so that at the discharge ends of the baffles they will link together to form waves of the desired output type.

6. A dielectric guide as claimed in Claim 3 provided with means for converting asymmetric magnetic waves to symmetric magnetic waves comprising a plurality of helical baffles adapted to rotate respective parts of the lines of electric force of the incoming waves and discharge them so that they will link together in coaxial circles to form symmetric magnetic waves.

7. A dielectric guide as claimed in Claim 6 comprising a main guide for the incoming asymmetric magnetic waves, a plurality of smaller parallel branch guides, respective helical baffles in said branch guides adapted to rotate the lines of electric force so that at the discharge ends of the said baffles they will link together in sequence in coaxial circles, and an outgoing dielectric guide connected around such discharge ends.

8. A dielectric guide as claimed in Claim 3 provided with means therein to convert electromagnetic waves from one to the other of the two types, asymmetric magnetic and asymmetric electric, in which said baffles consist of two conductors inside the guide with opposed kidney-shaped cross sections at one end and opening out to opposed arc-shaped cross sections at the other end.

9. A dielectric guide as claimed in Claim 3 provided with means therein to convert electromagnetic waves from one to the other of the two types, asymmetric magnetic and asymmetric electric, such means consisting of two conductors inside the guide with opposed kidney-shaped cross sections at one end and opening out to opposed arc-shaped cross sections at the other end, and longitudinal adjustable pistons within said conductors at their kidney-shaped ends.

10. A dielectric guide as claimed in Claim 3 provided with means to convert asymmetric electric waves to symmetric magnetic waves in a dielectric guide, comprising a pair of opposite conductors in the guide to receive the asymmetric electric waves, said conductors being brought closer together and one around the other as a coaxial conductor system going in the direction of propagation, and a transverse figure-8 frame with its two cross members connected respectively to said conductors, said frame being adapted to launch symmetric magnetic waves therefrom in the dielectric guide.

11. A dielectric guide as claimed in Claim 3 provided with means for converting waves of symmetric electric type to waves of asymmetric electric type consisting of an axial core and a cylindrical metallic shell, the axial core being bent off to one side of the guide and the cylindrical shell being bevelled off to the opposite side.

12. A dielectric guide as claimed in Claim 2 provided with means to convert asymmetric magnetic waves to symmetric magnetic waves consisting of a system of conductors lying in a plane transverse to the direction of transmission, each conductor comprising in series a chord part to receive the asymmetric magnetic waves and a circumferential part to radiate the symmetric magnetic waves, the chord parts of all such conductors being parallel and the circumferential parts extending consecutively around the axis along which transmission takes place.

13. A dielectric guide as claimed in Claim 3 provided with means for converting waves of symmetric electric type to waves of asymmetric magnetic type consisting of an axial core and a cylindrical conductive shell, said core being graded trough-like into a semi-cylindrical shell, and said cylindrical shell being bevelled to an opposite semi-cylindrical shell, and the resultant two semi-cylindrical shells being fused together.

14. A dielectric guide as claimed in Claim 3 provided with means for converting symmetric electric type waves to symmetric magnetic type waves, consisting of an axial core, two opposite radial members connected to the end of this core and semi-circumferential members connected to the ends of the radial members and to the wall of the guide at opposite points.

15. A dielectric guide as claimed in Claim 3 provided with means for converting waves of symmetric electric type to symmetric magnetic type, comprising a plurality of baffles placed edge to edge in a cylindrical contour at the input end and each twisted a quarter turn so that all stand radially at the output end.

16. A dielectric guide as claimed in Claim 15, comprising a plurality of baffles placed edge to edge in a cylindrical contour at the input end, the diameter of this assembly at that place having the proper ratio to the diameter of the dielectric guide for impedance match, each baffle being twisted a quarter turn and made wider in the direction of transmission so that at the output end the baffles all extend radially, and the diameter of the metal sheath being in-

creased gradually from the input end toward the output end.

17. A dielectric guide as claimed in any of the preceding claims in which a screen is placed across the guide on the output side to purify the waves of the outgoing type.

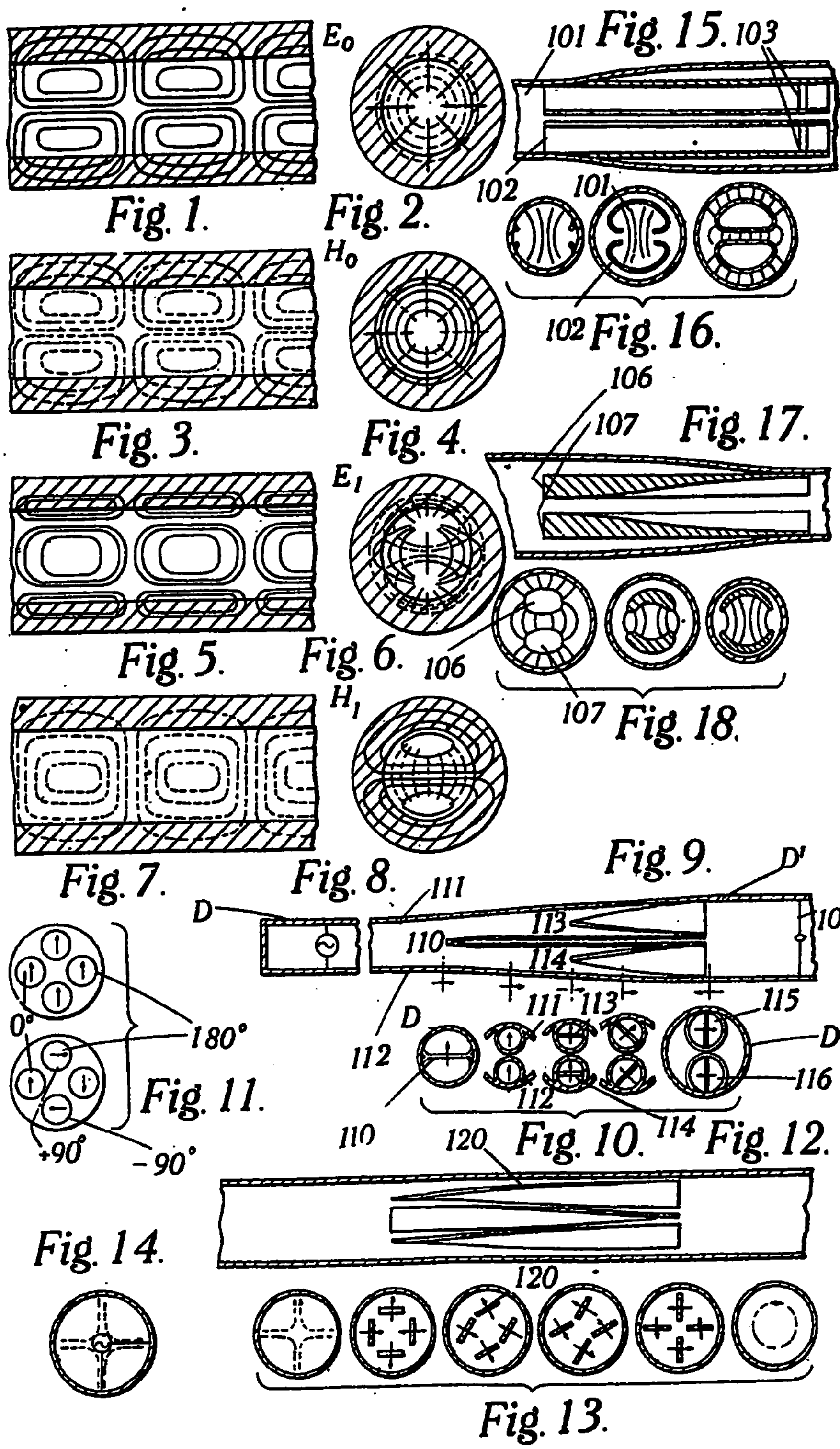
18. A dielectric guide as claimed in any of the preceding claims, in which said guide is made a different diameter on each side of the wave-converting means, the different diameters being appropriate to the respective wave type therein.

19. Arrangements for converting electromagnetic waves in a dielectric guide from one type to another as claimed in Claim 2 and substantially as described and as illustrated in the accompanying drawings.

Dated this 25th day of September, A.D. 1936.

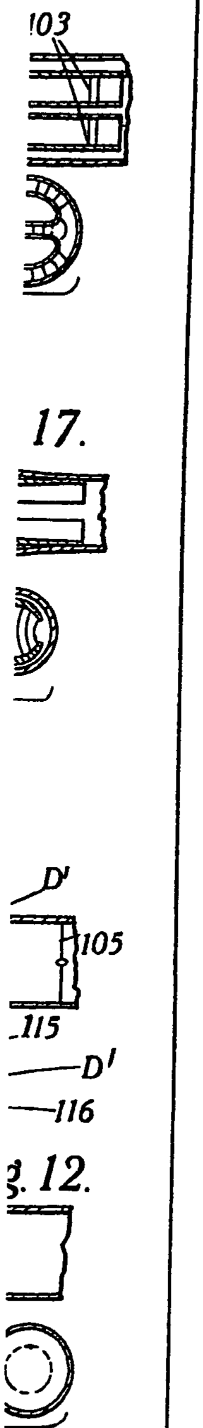
R. J. BERRY,
Chartered Patent Agent,
Agent for the Applicants,
Connaught House, 63, Aldwych,
London, W.C.2.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1937.



[This Drawing is a reproduction of the Original on a reduced scale.]

SHEET 1



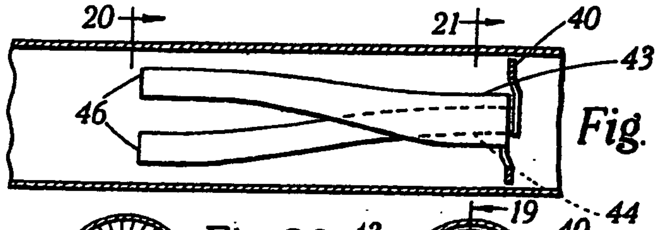


Fig. 19.

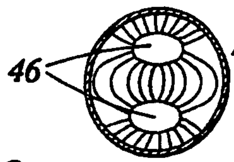


Fig. 20.

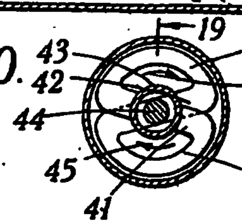
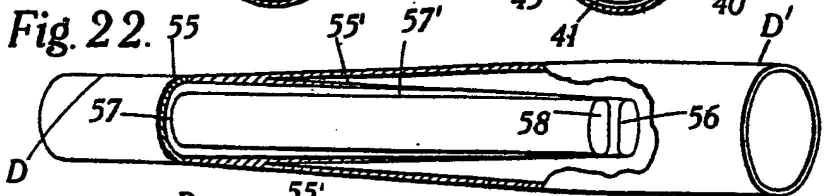


Fig. 21.

Fig. 22.



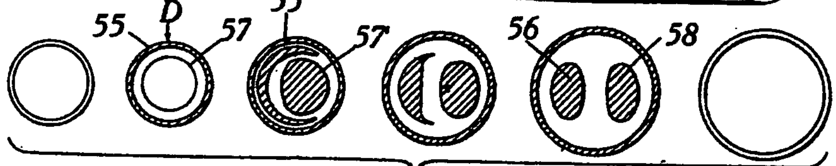


Fig. 23.

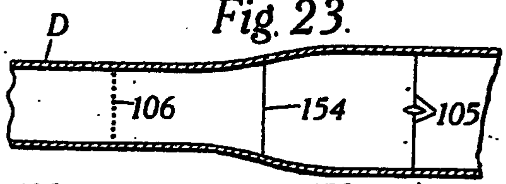


Fig. 24.

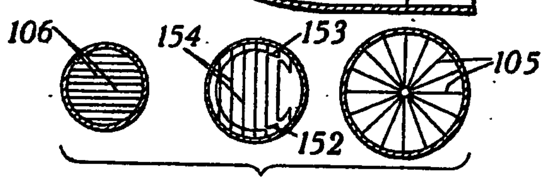
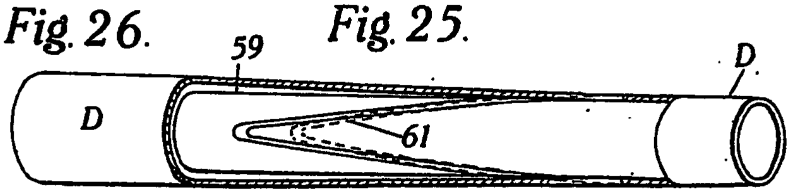


Fig. 25.

Fig. 26.



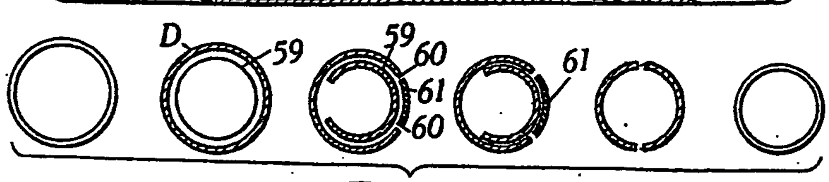
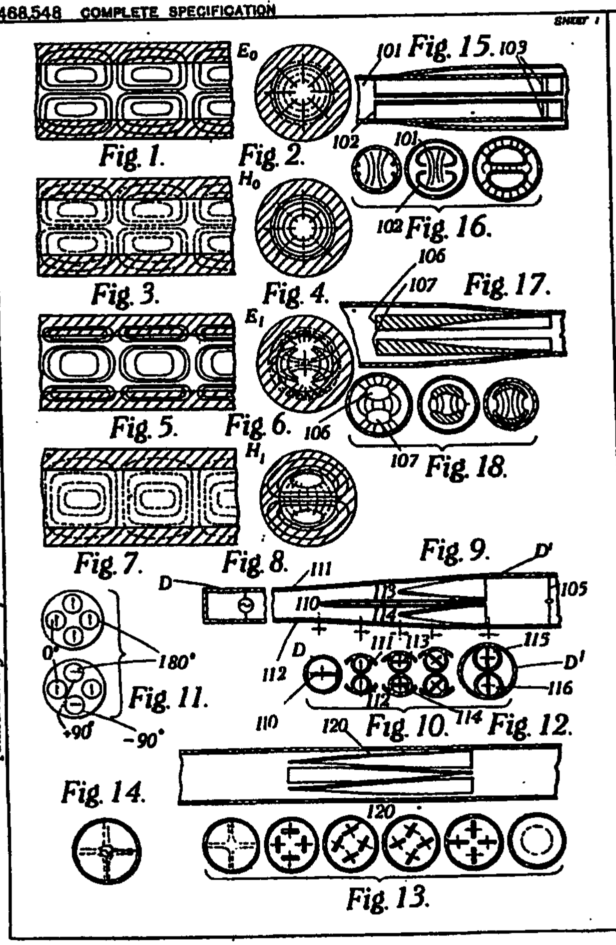
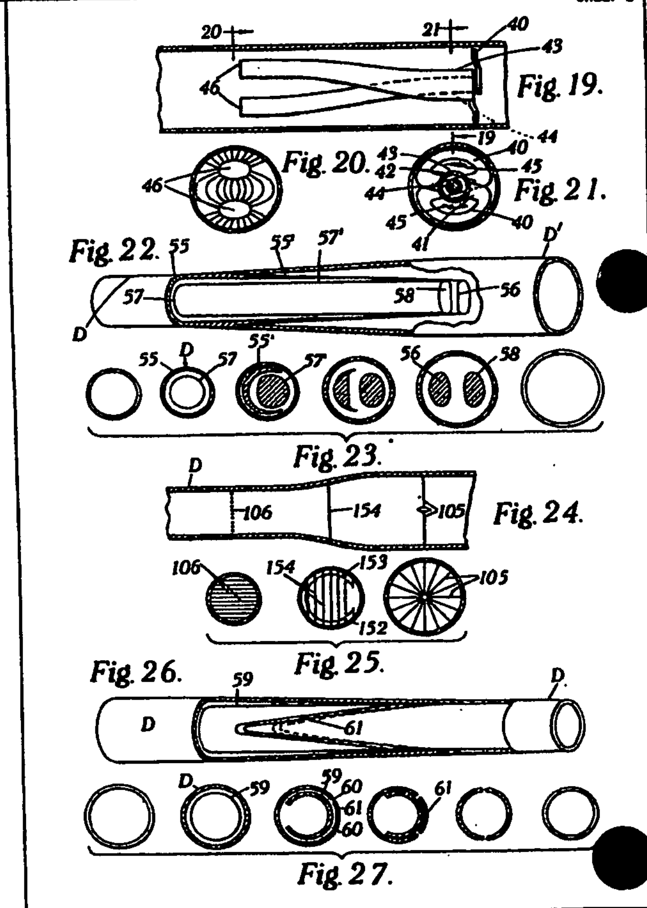


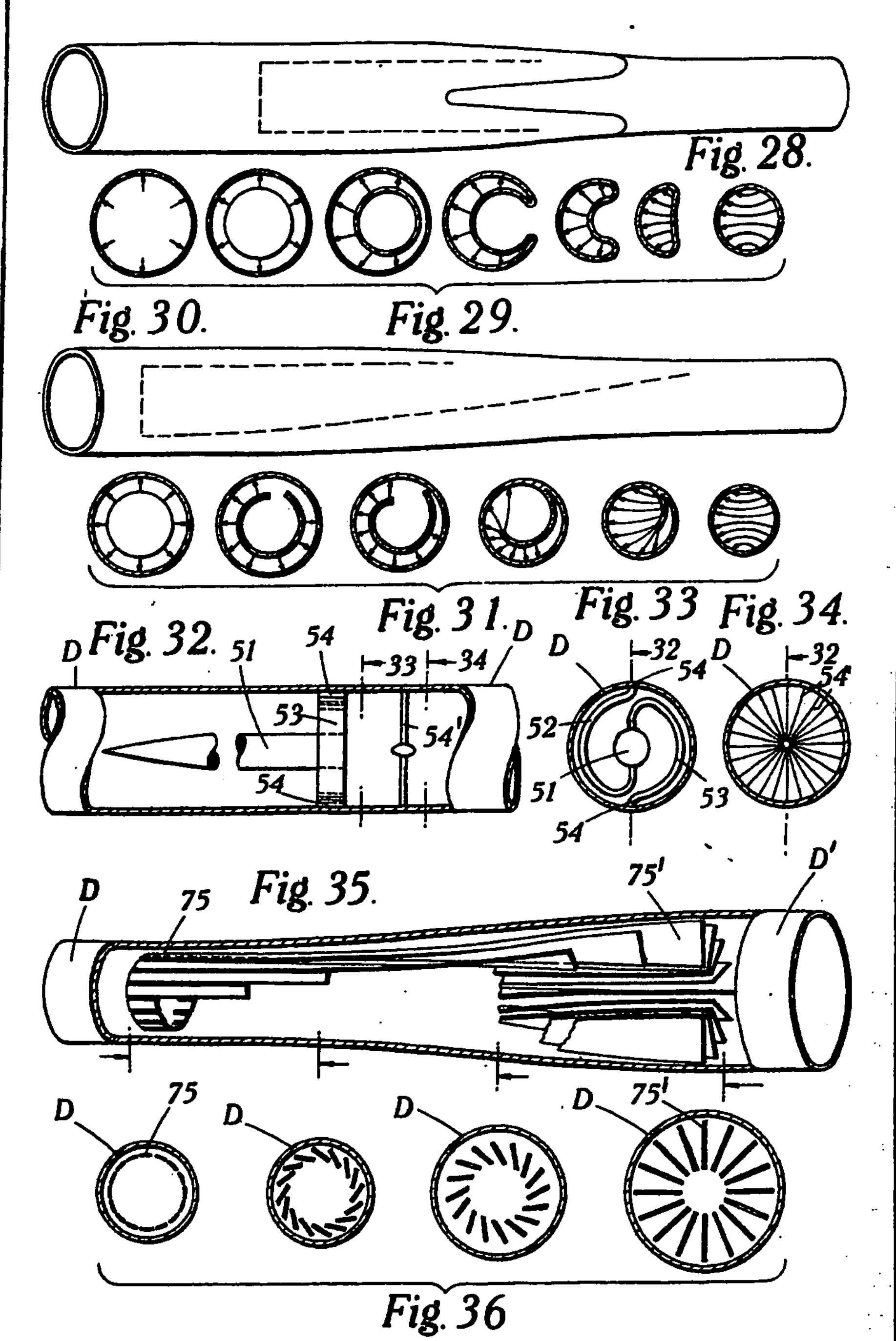
Fig. 27.

SHEET 1





[This Drawing is a reproduction of the Original on a reduced scale.]



[This Drawing is a reproduction of the Original on a reduced scale.]

This Page is inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- [x] BLACK BORDERS
- [x] IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- [x] FADED TEXT OR DRAWING
- [ ] BLURED OR ILLEGIBLE TEXT OR DRAWING
- [ ] SKEWED/SLANTED IMAGES
- [x] COLORED OR BLACK AND WHITE PHOTOGRAPHS
- [ ] GRAY SCALE DOCUMENTS
- [ ] LINES OR MARKS ON ORIGINAL DOCUMENT
- [ ] REPERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- [ ] OTHER: ______________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning documents *will not* correct images problems checked, please do not report the problems to the IFW Image Problem Mailbox